(3—4) 日御碕灯台の振動試験

正員 京都大学防災研究所 工博 ○横 尾 義 貫
正員 同 畑 中 元 弘

本灯台は明治 26 年に建設された本邦最高の灯台であるが，筆者らはその振動実験を行う機会をもつた。かかる構造物の振動測定例はきわめて少ないので一資料として報告し，その老朽性について若干の考察を加えてみる。

灯台の構造 基部外径 8.66 m，厚さ 0.83 m，頂部外径 5.0 m，厚さ 0.6 m，高さ 35.5 m の石造(凝灰質砂岩)で，内部に煉瓦積円筒壁を有している。構造の詳細は脚註文献を参照されたい[1]。

測定器械及び測定方法 振動計は石本式水平振動計 ($T=1.0$ sec, $V=200$倍, $\varepsilon=n$) 2 台を使用し，自然状態(主として風による振動)及び灯台頭部に碇着した番線をロープで引ききつた後の自由振動を測定した。

測定結果 a) 風による振動 自由振動週期 0.49～0.5 sec，最大振巾 6.3 μ (N 18°E)，及び 9.5 μ (S 72°E) 風速約 5.0 m/sec。

b) 引張り試験 (ロープの方向 N—S) 表—1 に測定結果を示した。

表—1

週 期 (sec)	最 大 振 巾 (μ)		減 衰 常 数		
	N18°E	S72°E	減 衰 比 v	ε	α
0.49～0.50	24.5～30.0	13.0	1.08～1.16	0.36～0.62	0.14～0.25

ただし $\alpha=1-1/v^2$

測定結果の考察 灯台を簡単に中空截頭錐体と考えると，自由振動週期から灯台の弾性率を推定することができる。物部博士の式[2]によると本例の場合には $\rho=2.45$ とすれば $E=5.9\times10^6$ t/m² が得られる。風化していない灯台構築材料より試験片を採取し，静的弾性係数及び密度を測定すると $\rho=2.45$, $E=5.9\sim6.5\times10^6$ t/m² となり，両者の E はほぼ同一である。また減衰性を示す α の値は 0.14～0.25，平均 $\alpha=0.19$ であり，これを物部博士の実測例[3]に較べると健全な煉瓦造構造物とこれが破損したものとのほぼ中間の値を有する。しかしながら目地の接着が煉瓦造よりもいくぶん不充分と考えられ，さらに振動波形がきわめて規則正しい減衰性を示しなんら異常の認められないこと，及び振動週期より推定した弾性率と直接試験片から測定した値とが大体等しいことなどを考え合わせると，本灯台の老朽性についても特に異常はないものと思われる。しかしながら本実測値と比較すべき構造物の資料が少ないので，振動状況に注意し数年後には再び測定の必要があろう。

註 1) 日本セメント技術協会: 灯台，コンクリートパンフレット，
2) 物部長穂: 土木耐震学，p. 212(153)式及び p. 213 上段の式，昭. 27
3) 〃 〃 p. 223 表—25

(3—5) ON THE GENERALIZED BOUSSINESQ'S PROBLEM.

By Bennosuke TANIMOTO, Faculty of Engineering, Shinshū University.

SINCE the time of Boussinesq, the theoretical basis for the problem of the safety of foundation has been discussed and developed by various investigators, of which the works due to Love and Terazawa will be noteworthy. The former gave the integration of the Boussinesq's potentials extending over a rectangular form of loaded area, together with the circular form of loading. He divided the method of treating the problem into two ways ; viz., "Boussinesq's potential method" and "Bessel function method", the latter being suitable for a circular form of loaded area. But as has been well known, the Boussinesq' s potential method cannot be compatible with any shearing forces, which would be of considerable importance especially in the case of soft foundation. The above classification due to Love may therefore be said to be of improper one.

I have proposed a set of functions which might be called stress-functions in three dimensions, and have obtained the solution of a Boussinesq's problem in which the semi-infinite elastic solid is pressed uniformly over a rectangular area. It was obtained in the form of Fourier's integral, and the evaluation of the integrals was relied on the method of mechanical cubature because of the difficulty of its analytical performance. As regards stresses there is no singularity in the integrands, so that the mechanical cubature has no serious difficulties, and to secure first two or three significant figures is not so laborious. Displacements can also be evaluated, though each of the integrands involved has one singularity at the origin of parametric coordinates. It would appear impossible to integrate Boussinesq's potentials by means of mechanical cubature, because of an infinite number of singularities in the integrands.

The article to be reported here is also an application of the proposed stress-functions, and corresponds to the generalization of the above boundary problem. It gives the solution of the most generalized Boussinesq's problem in which any distribution of shearing forces, as well as of normal pressure, is assumed as surface tractions, provided these can be expressed in terms of Fourier's integral. As simple applications of the above general solution, the following several cases will be given: an uniform pressure, a pressure varying in quadric surface, a shearing force of uniform distribution, a shearing force of triangular distribution in one direction, etc. These solutions can at once be written down from the above general solution. Numerical evaluation of the above solutions will be given, though they are for the time being of rough approximation.

Fundamental equations to be used are

$$\nabla^4\chi=0 \text{ and } \nabla^2\psi=0,$$

in virtue of which displacements are given by the operations

$$u=\left\{-\frac{\partial}{\partial x}\bar{\nabla}^2+(1-\sigma)\left(\frac{\partial}{\partial y}+\frac{\partial}{\partial z}\right)\nabla^2\right\}\chi+\left(\frac{\partial}{\partial y}-\frac{\partial}{\partial z}\right)\psi,\cdots\cdots,$$

where

$$\bar{\nabla}^2=\frac{\partial^2}{\partial y\partial z}+\frac{\partial^2}{\partial z\partial x}+\frac{\partial^2}{\partial x\partial y},\qquad \nabla^2=\frac{\partial^2}{\partial x^2}+\frac{\partial^2}{\partial y^2}+\frac{\partial^2}{\partial z^2},$$

and σ is Poisson's ratio of the material, v and w being given by cyclical interchange of letters. For actual calculation, preference is given to the forms

$$u=-\frac{\partial\phi}{\partial x}+\left\{-\frac{\partial}{\partial x}\bar{\nabla}^2+(1-\sigma)\left(\frac{\partial}{\partial y}+\frac{\partial}{\partial z}\right)\nabla^2\right\}\chi+\left(\frac{\partial}{\partial y}-\frac{\partial}{\partial z}\right)\psi,\cdots\cdots,$$

where $\nabla^2\phi=0$ and $\nabla^4\chi=0$; the former being well known as 'displacement-potential', and the latter being of 'proper' biharmonics. Stresses are then derived from Hooke's law.

Supposing that z-axis is drawn vertically downwards in the semi-infinite solid, the origin of coordinates being on the top surface, particular solutions suitable for the present problem are

$$\phi=(A_1\cos\alpha x\cos\beta y+A_2\cos\alpha x\sin\beta y+A_3\sin\alpha x\cos\beta y+A_4\sin\alpha x\sin\beta y)e^{-\gamma z},$$

$$\psi=(B_1\cos\alpha x\cos\beta y+B_2\cos\alpha x\sin\beta y+B_3\sin\alpha x\cos\beta y+B_4\sin\alpha x\sin\beta y)e^{-\gamma z},$$

$$\chi=(C_1\cos\alpha x\cos\beta y+C_2\cos\alpha x\sin\beta y+C_3\sin\alpha x\cos\beta y+C_4\sin\alpha x\sin\beta y)ze^{-\gamma z},$$

$A_1, A_2,\cdots\cdots C_3, C_4$ being constants; α, β and γ parameters provided $\alpha^2+\beta^2=\gamma^2$.

The above series of the work was done by S. Murata and M. Shimizu, both being students of the Faculty of Engineering, Shinshū University, as their graduation theses under my direction. I want to express my thanks to the Ministry of Education for giving me a financial aid, though not direct to the present work.